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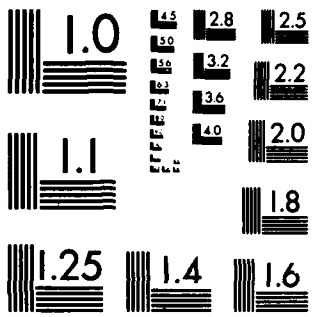

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Aircraft	Leadtimes
Budget Formulation	Cost Estimates

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This research, Phase IV of Contract F33615-81-C-5018 (see MCR TR-8104-3), was divided into three tasks:

a. Recommend data sources for FY-85 costs and leadtimes for BP 1500 Federal Supply Classes (FSC).

b. Recommend procedure for incorporating cost and leadtime adjustments in the FY-85 projected budget requirements.

(See reverse)

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6. Recommend specific price and leadtime adjustments for each Federal Supply Class.

The researchers examined cost and leadtime trends, by commodity, and developed factors to be used in refining the BP 1500 cost per flying hour estimates developed by the Logistics Management Institute's Aircraft Availability Model (AAM). In addition to developing factor values to represent projected cost and leadtime trends, the researchers identified sources of data which could be consistently used as part of the requirements estimating process.

MANAGEMENT CONSULTING & RESEARCH, INC.

TR-8229-1

POM FY85 BP 1500 COST GROWTH AND LEADTIME ADJUSTMENTS: RESEARCH RESULTS

By:

Patricia A. Insley
William P. Hutzler

28 February 1983

Prepared For:

United States Air Force
Business Research Management Center
Wright-Patterson AFB, Ohio 45433

Contract Number: F33615-81-C-5018

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PREFACE

Management Consulting & Research, Inc. (MCR) was tasked by the Air Force Business Research Management Center (AFBRMC) to research cost and leadtime trends for selected commodities in the aircraft replenishment spares (BP 1500) inventory. This research, Phase IV of Contract F33615-81-C-5018, was conducted under the technical direction of the Air Staff (USAF/LEX), during the period of 1 October 1982 to 28 February 1983, with the support of the Air Force Logistics Command (AFLC/LORA). This effort was divided into three tasks:

TASK 1 -- Recommend data sources for FY85 costs and leadtimes for BP 1500 Federal Supply Classes (FSC).

TASK 2 -- Recommend a procedure for incorporating cost and leadtime adjustments in the FY85 projected budget requirements.

TASK 3 -- Recommend specific price and leadtime adjustments for each Federal Supply Class.

This report summarizes the results of MCR's effort on these three tasks.

MCR wishes to express its appreciation to the Air Force contractors who have cooperated in this research and assisted by providing much of the data used in this analysis.

TABLE OF CONTENTS

LIST OF EXHIBITS

I. INTRODUCTION

In this section the following topics are discussed:

- the background of this study,
- the purpose of this research,
- the approach taken in conducting this research, and
- the organization of this report.

A. BACKGROUND

The Air Force annually presents its budget requirements to the Office of the Secretary of Defense (OSD) and the Office of Management and Budget (OMB). These requirements are developed and revised in the context of the Planning, Programming and Budget System (PPBS). Preliminary estimates are developed and presented in a Program Objective Memorandum (POM), presenting projections for the five-year period following the Budget Year (BY). The POM is used to define a financial framework in which subsequent budgets will be developed, and is a critical analytical stage in the PPBS. It is in this stage that long-term requirements projections are first developed and reviewed in detail. These preliminary estimates, developed five years in advance, is refined in each subsequent year until the actual budget is developed for the given fiscal year. The budget, therefore, is intended to fit within the requirements constraints defined in the POM. For this reason, accurately forecasting POM requirements is of vital importance.

This study is a continuation of research previously conducted for the Air Force Logistics Command, Deputy Chief of Staff for Logistics Operations (AFLC/LORA) under Contract F33615-81-C-5018, and sponsored by the Air Force Business Research Management Center (AFBRMC). The activities comprising the first three phases of this contract were directed toward developing a methodology for improving AFLC POM forecasting accuracy for aircraft replenishment spares (BP 1500). The methodology ultimately developed was designed to be integrated into the overall requirements determination process, compensating for those characteristics of the current determination process which could introduce errors with the requirements estimates.[1/]

The compensating methodology was based on a set of factors representing specific reasons why BP 1500 requirements could change. A set of five factors representing reasons for which the realism of the estimates could change were constructed. These factors are listed in Exhibit I-1. These compensating factors were designed to apply Parametric Estimating Relationships (PER) representing the collective effects of the five groups of reasons for requirements changes.

In addition to describing these factors, MCR also identified an approach for applying these factors to a raw (unadjusted) cost per flying hour (CPFH) factor developed by AFLC. Finally, potential sources of data were identified and discussed.

1/This research and the resulting methodology are described in detail in MCR report TR-8104-3, Summary of Analysis of Sources of Forecasting Errors in the BP 1500 Requirements Estimating Process and Description of Compensating Methodology, Patricia A. Insley and others, 25 April 1982.

Reasons for Requirements Changes / Realism Factors	Program Changes R-1	Financial R-2	Inventory Status R-3	Design Engineering R-4	Economic Escalation R-5
Modifications	X				
Schedule	X				
Flying Hour Program	X				
Management Decisions	X				
Additives	X				
Supplier Data		X			
Unit Price		X			
Quantity Changes		X			
Program-Change Related Escalation		X			
R&M/Failure Rates			X		
Condemnation Rates			X		
Inventory Contents			X		
Changes in Stock Levels			X		
Technology Type				X	
System Age				X	
Geographic Location				X	
Critical Material Requirements				X	
Inflation Rates					X

Exhibit I-1. REALISM FACTOR RELATIONSHIPS

As a result of this research, MCR was originally tasked by AFLC/LORA to continue with a fourth phase of research. The purpose of this research was to identify specific data sources to be used in developing values for the Program Changes, Inventory Status and Design/Engineerng factors. In addition to identifying data sources, this effort was to identify types of data necessary to calculate the factor values and develop and demonstrat a method for calculating actual factor values.

While conducting the research of possible data sources, MCR's Phase IV tasking was revised and technically redirected to provide immediate support to the Headquarters of the Air Force, Deputy Chief of Staff for Logistics and Engineering (HQ USAF/LEX). This revised tasking, while also addressing POM BP 1500 requirements forecasting, was concerned with developing commodity-specific cost and leadtime adjustment factors for the FY85 POM. Thus, this report's emphasis is on MCR's research in support of the Air Staff. However, this report also documents MCR's initial efforts in support of the original AFLC tasking (Appendix A).

B. PURPOSE

As noted above, the POM plays a critical role in the budgetary process. In recent years, BP 1500 requirements have increased substantially between the POM and the budget. Several efforts have been undertaken by different groups within the Air Force to study the reasons for this forecasting inaccuracy and develop methods to improve it. MCR's previous research was one such study.

In this study, which continued the research begun in the previous effort, particular concern has been with the item costs and production leadtimes on which these estimates are based. Previous surges in demand in the aerospace industry have resulted in significant and sudden increases in both of these areas.

The purpose of MCR's revised study was to examine cost and leadtime trends, by commodity, and develop factors to be used in refining the BP 1500 cost per flying hour estimates developed by the Logistics Management Institute's (LMI) Aircraft Availability Model (AAM). In addition to developing factor values to represent projected cost and leadtime trends, this study was also concerned with identifying sources of data which could be consistently used as part of the requirements estimating process.

The BP 1500 requirements estimating process is largely dependent on the historical acquisition data in the "Recoverable Consumption Item Requirements System" (D041). Cost, leadtime and supplier information is usually based on the last acquisition of an item. Experience has shown that these historical data can be woefully inaccurate. Procedures for updating this information exist, with contractors' quotes acceptable as the basis for updating costs and AFLCR 84-4 used to update production leadtimes. This regulation allows the surveying of contractors to determine the current leadtimes for items they produce. The effectiveness of the AFLCR 84-4 usage was reconsidered by the AFLC LO/PM Working Group on Increasing Production Lead

Times.[2] After surveying various groups within the Air Force logistics community, measures were taken to improve the effective usage of this procedure. However, interest still exists in whether there are additional methods for improving production leadtime estimates. These concerns were to be considered in conducting this research.

C. APPROACH

MCR's revised Phase IV research was organized around three tasks:

- identify potential sources of data;
- develop procedures for integrating research results in the LMI/AAM calculations; and
- develop commodity-specific factor values for costs and leadtimes.

Of interest in the first task were sources of data of immediate use in analyzing cost and leadtime trends and developing commodity-specific factors. As noted earlier, USAF/LEX was also interested in determining if there were additional, stable sources of data which might not be adequately represented in the current BP 1500 requirements analysis process, or which could be incorporated in future analyses.

The second task reflected the intended use of the MCR research results as input data for the LMI Aircraft Availability Model. The nature of that model, in conjunction with the nature of the

2/Report of the LO/PM Working Group on Increasing Production Leadtimes, Air Force Logistics Command Deputy Chiefs of Staff for Logistics Operations and Contracting and Manufacturing, February 1981.

type of information MCR discovered (a mixture of qualitative and quantitative data), ultimately indicated that application of these results was more practical as external adjustments to the model input data. Both LEX and LMI found this to be an acceptable implementation approach.

The third task focused on compiling the collected data in a manner which allowed its presentation as a set of commodity-specific cost and leadtime factors. To the degree possible, this information has been presented as a quantified estimate. However, in those cases where this was not possible, a trend indicator has been given instead.

D. ORGANIZATION OF THE REPORT

This report is organized in four major sections and a set of appendices. Following this introduction, the organization of MCR's research is described in Section II. An overview of characteristics and trends in the aerospace industry is presented in Section III. The commodity-specific cost and leadtime factors developed in this study are presented in Section IV. MCR's conclusions and recommendations are contained in Section V. There are two appendices. Appendix A contains a brief discussion of MCR's research efforts in support of the original AFLC Phase IV tasking. Appendix B contains the lists of data sources used in this report.

II. ORGANIZATION OF THE RESEARCH

The following topics are presented in this section:

- a discussion of the structure of the MCR analysis, and
- the identification of data sources.

A. STRUCTURE OF THE ANALYSIS

A major consideration in structuring the research for the revised Phase IV tasking was the need to define the effort within the cost and schedule terms of the existing contract. Given that the contract terms for Phase IV had been based on a different set of tasks, the research for the revised tasking had to be structured to respond to these constraints.

In addition, there were several significant analytical concerns identified by MCR at the start of this effort. As originally discussed with LEX, the intention was to develop factors for all of the commodities or Federal Supply Classes (FSC) represented in the BP 1500 inventory. This was found to be impractical due to the number of FSCs involved. In addition, only a small number of FSCs were believed to be of real influence in the total requirements. It was decided that the set of "most significant" FSCs would be the MCR reseach targets.

As in the previous AFLC tasking, major emphasis was on developing quantitative data. However, the broader scope of the research goals, the more general nature of the factors which could influence cost and leadtime projections, and the overall analytical effort of which this research was a part argued that if qualitative

information was available, it should also be represented. The tentative nature of the ultimate application of the factors supported this decision.

Finally, there was concern about the comprehensiveness of the research which could be performed within the existing time and funding constraints. This concern influenced the direction of the research in that, in cases where substantial amounts of time were needed to develop a data source, the data source generally not pursued. Whenever possible, alternate sources were identified and used. In addition, emphasis was placed on non-Air Force sources because internal Air Force sources are, hopefully, already adequately represented in the process.

With these thoughts in mind, the research was conducted in the following sequence:

- Identify research targets (Federal Supply Classes and aircraft types),
- Develop data request,
- Identify groups to be contacted,
- Submit data request to selected manufacturers,
- Determine types of available information,
- Construct appropriate factor integration procedures, and
- Compile data.

Resources were organized to primarily focus on the first Phase IV task, identification of data sources, and collection of data. The first step in this process was the identification of the specific research targets. This involved determining the

"most significant" FSCs. The ten "most significant" FSCs are listed in Exhibit II-1, in the order of their impact in the BP 1500 inventory. This selection was based on analysis of the distribution of D041 requirements by FSC, using data provided by LMI. This group of FSCs was approved by the Air Force prior to the pursuit of the identification of potential sources of data. To be included in this list, the total requirement for an FSC had to amount to at least two percent of the total D041 requirements estimate in terms of cost.

Although the primary emphasis of our study was to develop factors by FSC, the potential relationship of requirements to Cost Per Flying Hour (CPFH) factors could not be ignored. This was particularly true if, as believed, several of the FSCs were influenced by aircraft type. For these reasons, it was decided to also identify the "most significant" aircraft types, as represented in the inventory. These aircraft types are also listed in Exhibit II-1 by Mission-Design. The aircraft types were selected based on analysis of historical flying hour program data, originally provided by AFLC in the Phase I-III effort of of this contract. Those aircraft types with flying hour programs generally greater than 100,000 hours per year were considered to have more significant influence on the inventory than those with smaller flying hour programs. In addition, only fixed wing aircraft were selected. Finally, trainers, while having large flying hour programs, were eliminated. The list of selected aircraft types was reviewed and approved by the Air Force.

FSC	TITLE
2840	Gas Turbines & Jet Engines, Aircraft, and Components
1560	Airframe Structural Components
5865	Electronic Countermeasures, Counter-Countermeasures, and Quick Reaction Capability Equipment
1620	Aircraft Landing Gear Components
2915	Engine Fuel System Components, Aircraft
6605	Navigation Instruments
1270	Aircraft Gunnery Fire Control Components
1280	Aircraft Bombing Fire Control Components
5841	Radar Equipment, Airborne
5960	Electron Tubes & Associate Hardware

AIRCRAFT TYPES

A-7
A-10

B-52

C-5
C-130
C-135
C-141

E-3

F-4
F-15
F-16
F-111

Exhibit II-1. RESEARCH TARGETS:
FEDERAL SUPPLY CLASSES AND AIRCRAFT TYPES

The "most significant" aircraft types were primarily used in determining those manufacturers to be contacted for aircraft-specific FSCs such as structural components and landing gears.

B. IDENTIFICATION OF DATA SOURCES

As noted above, a standardized data request was formulated. This approach was taken because it allowed for the development of a consistent, comprehensive request which could be tailored, when necessary, to a particular recipient. A single generic set of questions was drafted for the purpose of identifying and addressing the major factors influencing system cost and leadtime.

As mentioned earlier, this research focused on identifying:

- data which could improve the accuracy of near-term commodity cost and leadtime estimates, and
- data not adequately represented in these estimates.

Two major categories of sources were identified:

- those organizations providing cost and leadtime data to the Air Force, specifically the manufacturers of BP 1500 items; and
- those organizations reporting on various aspects of the aerospace industry which might or might not be incorporated in BP 1500 estimates.

The manufacturers were considered the most desirable source of data since it is their actual costs and leadtimes which had to be represented accurately in the data analysis. Thus, MCR developed a data request which was designed to address the drivers of manufacturing costs and production leadtimes.

The non-manufacturing data sources were evaluated in terms of more generic trends present in the aerospace industry. This will be discussed in more detail later.

The contents of the data request submitted to BP 1500 manufacturers are listed below.

- Near-term (FY83-85) projections on average cost increases for the systems/spares the contractor produces for the Air Force in the selected Federal Supply Classes (FSC).

- Descriptions of analytical techniques and/or indicators which the contractor has found useful in developing cost growth projections and production leadtime projections (e.g., Data Resources, Inc. (DRI) indices, internal data monitoring, etc.), the current methodology for developing unit price estimates as well as the current unit price estimates for each system. (Does the contractor do independent cost estimates/requirements estimates for spares for the systems manufactured?)

- Identification of most significant cost drivers for each system.

- Information on the unit cost and leadtime impacts of ordering spares for:

  - systems employing older performance technology and/or manufacturing technology; and

  - systems which are no longer in production.

- Information on the cost impacts of any of the above problems combined with very small (less cost effective) ordering quantities. This may relate more to historical experience; however, a basic explanation of how these conditions influence cost (e.g., ordering of production-lot quantities of materials) was requested.

- Information on the status of material-supplier availability, if projections have been made in terms of cost and leadtime impacts on projected supplier status for particular materials (e.g., critical/exotic materials, large forgings and castings, special coatings, etc.)

- Potential problems due to limited industrial capacity, competition with commercial industry, etc.
- Projected cost and leadtime impacts of:
  - new manufacturing technology, and
  - new cost growth monitoring methods.
- Identification of those components in the contractor's system(s) which have the longest leadtime; the reasons for the long leadtime; the length of the leadtime; and any historical data available on the leadtimes actually experienced for those components.
- Impacts on requirements due to installation on certain aircraft types, or deployment of aircraft in certain climates, environments, etc.
- List of system subcontractors.
- Current backlog of sales for the relevant manufactured systems.

The MCR data source identification effort took the form of an informal survey, designed to be as comprehensive as possible. Listings of potential sources of data were used whenever available. However, they were frequently found to be very difficult to obtain, or had insufficient detail to be able to determine if the items manufactured were of actual interest for the research. Ultimately, a variety of sources was used to compile the list of recipients of the data request. As would be expected, some of those sources were of more use than others.

The manufacturers to which this data request was submitted are listed in Exhibit II-2. The responsiveness of these manufacturers is discussed in Section III.

In addition to manufacturers, a variety of other potential data sources were identified and evaluated. These non-manufacturing data sources included:

Manufacturer	Division	Federal Supply Class
Bendix Corporation	Air Transport Division Energy Control Systems Division Aircraft Brake and Strut Division Flight Division	Radar Equipment, Airborne Engine Fuel System Components Aircraft Landing Gears Navigation Instruments
Boeing Military Aircraft Company		Airframe Structural Components
General Dynamics Corporation		Airframe Structural Components
General Electric Corporation	Aircraft Engine Division Aircraft Equipment Division, Aircraft Instruments Department Aerospace Electronic Systems Dept. Aerospace Control Systems Dept. Armament and Electrical Systems	Gas Turbines & Jet Engines Engine Fuel System Components Radar Equipment, Airborne Navigation Instruments Aircraft Gun and Bomb Fire Control Components
Grumman Aerospace Corporation		Airframe Structural Components
Honeywell, Inc.	Military Avionics Division	Radar Equipment, Airborne Navigation Instruments
Lockheed Corporation	Lockheed-Georgia	Airframe Structural Components
McDonnell-Douglas Corporation		Airframe Structural Components
Menasco, Inc.	California Division	Aircraft Landing Gears
Pratt & Whitney Aircraft	Government Products Division	Gas Turbines & Jet Engines
Texas Instruments, Inc.	Radar Systems Division	Radar Equipment, Airborne
Varian Associates		Electron Tubes & Associated Hardware
Westinghouse Electric Corporation		Electronic Countermeasures, etc.
Wyman-Gordon Company	Eastern Division	Gas Turbines & Jet Engines Airframe Structural Components (forging and castings)

Exhibit II-2. MANUFACTURERS RECEIVING DATA REQUEST

- Government agencies,
- trade associations,
- economic analysts,
- regularly generated reports,
- special studies and proceedings,
- periodicals, and
- bibliographic searches.

The organizations contacted, in addition to the BP 1500 manufacturers, are listed below:

- Department of Commerce, Bureau of Industrial Economics;
- Department of the Interior, Bureau of Mines,
- Aerospace Industries Association,
- Electronics Industries Association,
- American Industrial Resources, Inc.,
- National Science Foundation,
- The Rand Corporation,
- Data Resources, Inc.,
- Garfield Schwartz Associates,
- National Tooling and Machining Association; and
- National Association of Manufacturers.

In addition to the organizations contacted, a variety of published sources were reviewed. The reports containing specific information of use (either detailed or general) are listed below:

- U.S. Industrial Outlook, with four-year projections,
- Mineral Commodities Summaries,

- Minerals Yearbook,
- Producer Prices and Price Index,
- Employment and Earnings,
- Survey of Current Business,
- Census of Manufacturers,
- Survey of Manufacturers, and
- Current Industrial Reports.

All of these reports are published regularly, with the frequency of the publication varying from monthly to every five years. The limiting factor on the utility of these reports was the level at which industries and commodities were addressed, usually by Standard Industrial Classification (SIC) Code or the associated commodity code. This requires interpreting the applicability of the information to a differently organized commodity classification system such as the FSC. The actual reports, as well as the special studies and proceeding used in this research, are listed in Appendix B.

In addition to these regularly generated reports and special studies, the following periodicals were also reviewed:

- Aviation Week and Space Technology,
- Business Week,
- Forbes,
- Fortune, and
- Air Force Magazine.

Periodicals were a primary source of data for this study. They were generally found to be of greater usefulness because of the currency of their contents and the specialized topics which could be examined in detail. The most useful periodical was found to be Aviation Week and Space Technology for these reasons as well as its close identification with the aerospace industry. Business Week, Forbes, and Fortune provided more general information about the status of manufacturers and the industrial base, and potential economic trends. Air Force Magazine was found to be of limited use. Time did not allow for a detailed review of the more specialized technical journals such as Spectrum and Metals Week, which may provide useful technical detail.

Several bibliographic searches were also made, and are listed below:

- Defense Technical Information Center (DTIC),
- Defense Logistics Studies Information Exchange (DLSIE),
- General Accouting Office (GAO),
- National Technical Information Service (NTIS),
- The Rand Corporation, and
- Logistics Management Institute.

Few studies of value were identified through the bibliographic search method. A more effective source of information on the existence of useful reports was found to be individual recommendations of analysts involved in related research, since there was a general desire to keep abreast of analyses and reports relating to their interest. Further contact with other

professional and technical associations would probably yield additional studies of interest. It should be noted that such studies tended to provide more second order information, of use in interpreting specific data and in projecting general trends. The specific studies used in this research are listed in Appendix B.

While a substantial number of data sources were identified in this task, it is recognized that, given more time, additional data sources might have been identified. Also, given the short, five-month period for identifying, collecting and analyzing the data, potentially useful data sources, particularly manufacturers were not developed as much as desired.

The published data sources were reviewed using an extensive list of key words designed to reflect the major drivers and elements of concern which could inflence manufacturing costs and leadtimes. The list of key words is provided below.

- Aircraft Replenishment Spares Forecasting
- Aerospace Industry
  - Castings and Forging Capacity
  - Capacity
  - Suppliers
  - Backlog of Orders
  - Major Manufacturers
  - Materials Composition
- Critical/Strategic Materials
  - Titanium
  - Chromium
  - Tantalum
  - Aluminum
  - Cobalt
  - Ferrous and Non-ferrous Metals
  - Minerals Availability
  - Minerals and Metals Suppliers
  - Materials Processing
  - Minerals and Metals Costs

- Exotic Materials
  - Alternative Applications
  - Composites
  - Rapid Solidification
- New Manufacturing Technologies
  - CAD-CAM
  - Near Net-Shape Castings
  - Single Crystal Castings
  - Robotics
  - Laser Technology
  - New Management Theories
- Budget Planning
- Air Force Force Planning
- Readiness and Availability
- Status of the Economy/Economic Forecasting
- Electronics
  - Systems
  - Industry
  - Technological Forecasting
  - Manufacturers
  - Component Suppliers
  - Advanced Applications
- Avionics
  - Industry
  - Systems
    - Navigation Systems
    - Radar Systems
    - Auto-Pilots
    - Gyroscopes
    - Electronic Warfare
    - Electronic Countermeasures
    - Electronic Countercountermeasures
- Air Force Aircraft and Missiles

- A-7	- C-141
- A-10	- E-3
- B-52	- F-4
- B-1	- F-15
- C-5	- F-16
- C-130	- F-111
- C-135	- MX

- New Maintenance Techniques
- Selected Manufacturers
- Aircraft Propulsion Systems
  - New Manufacturing Techniques
  - Materials
  - Castings and Forgings
  - New Coatings
  - Testing
  - Supplier Capacity
  - Manufacturing Facilities
- Airframe Structural Components
  - Wings
  - Composite Materials
  - Skins
  - Windshields
  - Structural Framing and Struts
- Aircraft Landing Gears
  - Tires
  - Brakes
- Fire Control Systems
  - Gun
  - Bomb
- Electron and Traveling Wave Tubes

As a result of the data source research, five general types of data were identified:

- commodity-specific historic cost and leadtime information,
- SIC-specific industrial trends,
- general aerospace industrial economic trends,
- manufacturing technology trends, and
- information on aerospace material status.

Commodity-specific information was primarily obtained from the manufacturers, in response to the data request. The remaining

types of information were gathered through MCR's review of the reports, studies and periodicals. This information has been used in the development of the factors in that it provides additional background understanding of trends which can influence both near- and long-term cost and leadtime projections.

As noted earlier, it was ultimately decided to integrate the results of the MCR analysis with the estimates developed by the LMI/AAM external to the model. The factors developed in this study, because they are meant to be applied external to the AAM, are designed to be used as the basis for refining the data input for the LMI/AAM.

The actual data collected and the cost and leadtime projections for the selected commodities are discussed in the following section.

III. OVERVIEW OF CHARACTERISTICS AND TRENDS IN THE AEROSPACE INDUSTRY

The following topics are discussed in this section:

- Manufacturing cost and leadtime drivers, and
- Construction and application of commodity groups.

Before discussing the specific cost and leadtime trends identified by MCR for the selected BP 1500 commodities, it is useful to consider some of the characteristics of the industry in which most of these items are produced. While many of these characteristics are common to any manufacturing process, their impact is frequently more intense in the aerospace industry. These characteristics are discussed in terms of their role as general drivers of cost and leadtimes.

Also, for portions of the analysis, it has been more effective to group the FSCs into commodity groupings. These groupings have been made primarily on the basis of common material composition. The construction and application of these commodity groupings are also discussed.

A. MANUFACTURING COST AND LEADTIME DRIVERS

Interviews with manufacturers and reviews of studies on the reasons why manufacturing costs and leadtimes increase tended to consistently identify the same set of key drivers. Virtually the same set of drivers was also found to influence both costs and leadtimes, with some tending to influence costs more, and some tending to influence leadtimes more. These key drivers are:

- production status of the item (i.e., in production or out of production),
- materials requirements and availability,
- manufacturing and design technology,
- supplier availability (i.e., second and third tier vendors),
- labor costs and availability, and
- quantity ordered.

Each of these drivers is briefly discussed below.

1. Production Status of Item

Perhaps the most significant driver in production costs and leadtime, as well as in the ability of the manufacturer to estimate them, is an item's production status. This term refers to whether the item is currently in production or not. While manufacturers can usually estimate near-term production costs and leadtimes for items they currently or recently have produced, they generally will not estimate cost or leadtimes for items no longer in production.

The criteria for determination of production status is set by the manufacturer, without an accepted standard criteria. Manufacturers tended to indicate that an extended period between orders, such as two to three years for jet engine spares, was the general rule of thumb. However, a variety of other factors, particularly those considered as key production cost and leadtime drivers, can also influence the determination of an item's production status, since the term largely relates to a firm's ability to produce the item. Factors such as the following

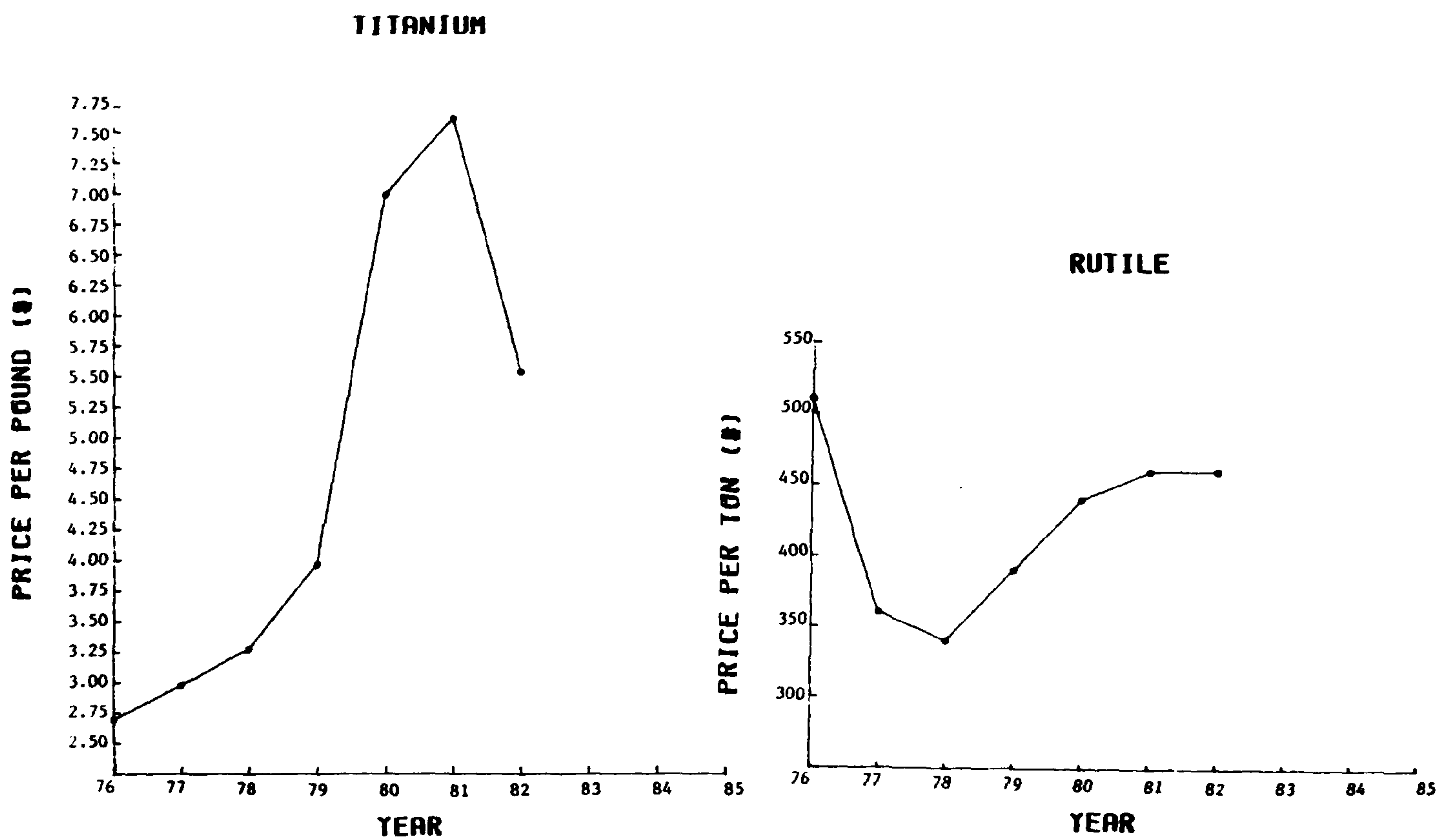
contribute to an inability of manufacturers to realistically estimate costs and leadtimes for out-of-production systems:

- the uncertainty of suppliers,
- the need to reproduce older technology (both manufacturing and design),
- the duplication of materials which may no longer be readily available, and
- the need to retool for a frequently small production run.

For these reasons, manufacturers also do not maintain ongoing estimates for systems which could need spares at some later date. In other words, the costs and leadtimes for out-of-production systems are, for practical purposes, unknown. The degree to which they differ from the last acquisition depends on the item and manufacturer. It should be noted that all of the manufacturers indicated that there was no cost difference between the parts assembled in a full system and parts that are spares for that system, when the system was in production.

2. Materials Requirements and Availability

The materials from which an item is constructed, along with the labor cost to produce the item, account for the major portion of an item's cost and leadtime. Aerospace systems frequently require costly materials such as titanium and cobalt. The surge in demand in the aerospace industry between 1979 and 1981 produced significant and sudden rises in costs and leadtimes for the major aerospace materials. Exhibit III-1 illustrates the recent cost trends in selected materials. The recent pattern of



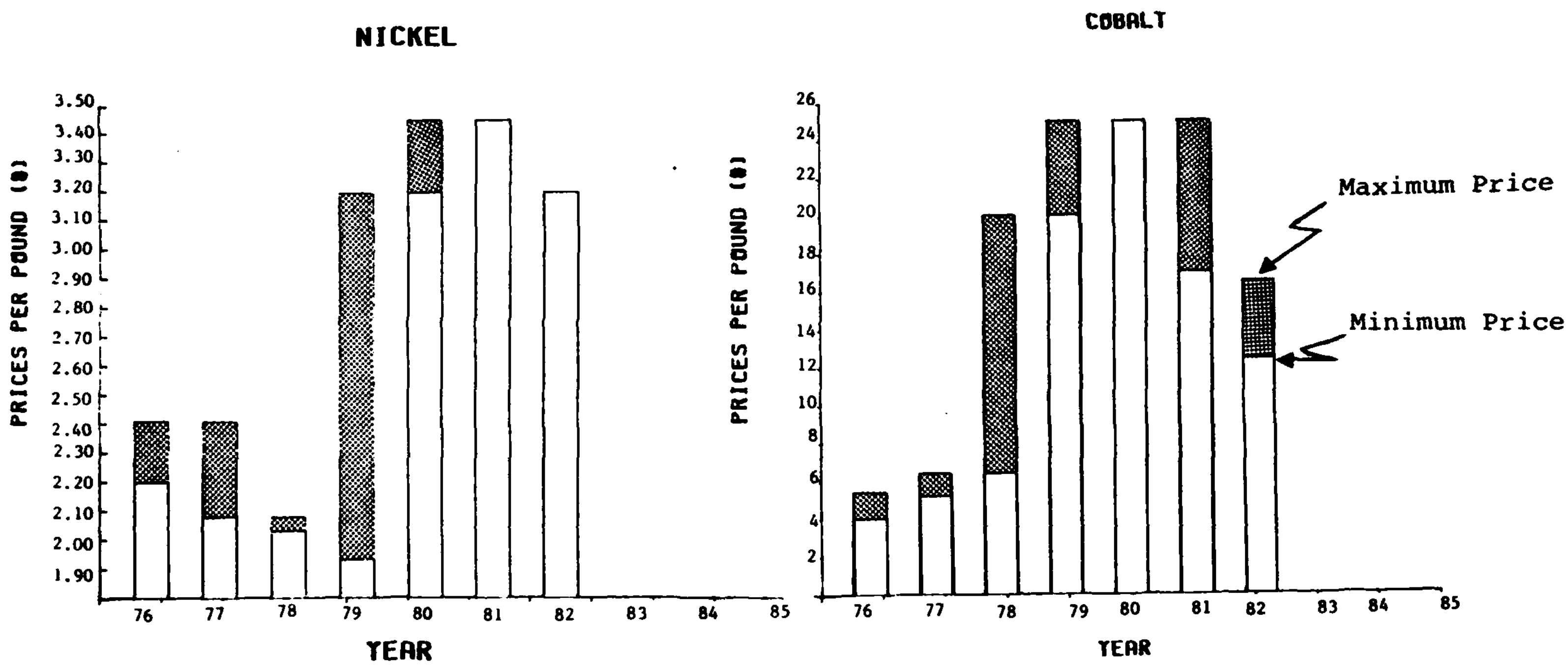
Source: 1982 Mineral Commodity Summaries

Exhibit III-1. AEROSPACE MATERIALS COST TRENDS
A. TITANIUM AND RUTILE

costs tend to indicate that a substantial increase in the future demand could produce similar responses. As noted in later discussion, many of these materials are critical elements in BP 1500 items.

As can be seen, a significant increase in several of the materials occurred in the 1979 to 1981 timeframe. 1982 prices indicate a trend towards the lower prices of the pre-surge period. The amount which the prices for most of these materials will decrease will largely depend on the recovery of the economy, the status of the commercial aircraft industry (currently depressed), and foreign trade decisions affecting the strategic materials stockpile. One of the contributing factors to the staggering increase in titanium prices (Exhibit III-1A) during the surge period was the substantial decrease in imported titanium sponge from Japan and the Soviet Union. As indicated in the graph of rutile prices, the material from which titanium sponge is produced, prices, while increasing, were not as steep as those experienced by the processed material.

Both cobalt and nickel (Exhibit III-1B) have significant roles in modern engine designs. As noted in the graphs, costs increased substantially during the surge period for both of these materials. Although not always possible, nickel can be used in an alloy as a substitute for cobalt. Cobalt plays a critical role not only in the production of jet engines but also in the production of machine tools used throughout the aerospace industry. Due to its properties of hot-hardness, ferromagnetism, color and chemistry, it is also used in the production of construc-

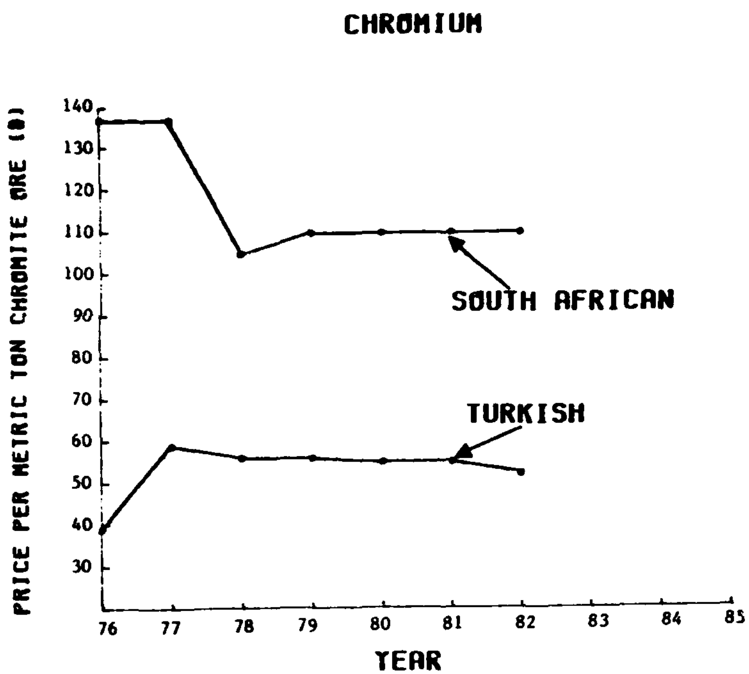


Source: 1982 <u>Mineral Commodity Summaries</u>

Exhibit III-1. AEROSPACE MATERIALS COST TRENDS
B. NICKEL AND COBALT

tion machinery, welding rods, paints, chemicals, ceramics and magnets. Cobalt can play a significant role in jet engine materials requirements. For example, in the F-100 engine, the raw material, or "buy" weight includes 900 pounds of cobalt, which, after production, produces a "fly" weight of 150 pounds of cobalt. While substitution and techniques such as near-net shape casting can reduce the initial material requirement, new technology and performance demands are creating larger roles for materials such as cobalt and titanium. New engines may have between 35 and 47 percent of their weight in titanium, approximately 10 percent in cobalt, and another 27 percent in nickel. Price fluctuations in these materials can have a major impact on total system costs. The shaded areas indicate the range of high and low prices paid during the year.

Chromium (Exhibit III-1C) is the only one of the selected materials which did not experience significant cost growth, as indicated by the price history for South African and Turkish chromite ore. The major reason for this price stability appears to be the expanding of the market to include previously unacceptable grade ores, primarily due to dramatic improvements in metals processing techniques. While techniques such as materials substitution can reduce the amount of raw material required to produce a part or component, this is usually not possible in the case of chromium. Reductions in chromium for most aerospace applications tend to produce an associated reduction in performance. It should be noted that, in practice,



Source: 1982 <u>Mineral Commodity Summaries</u>

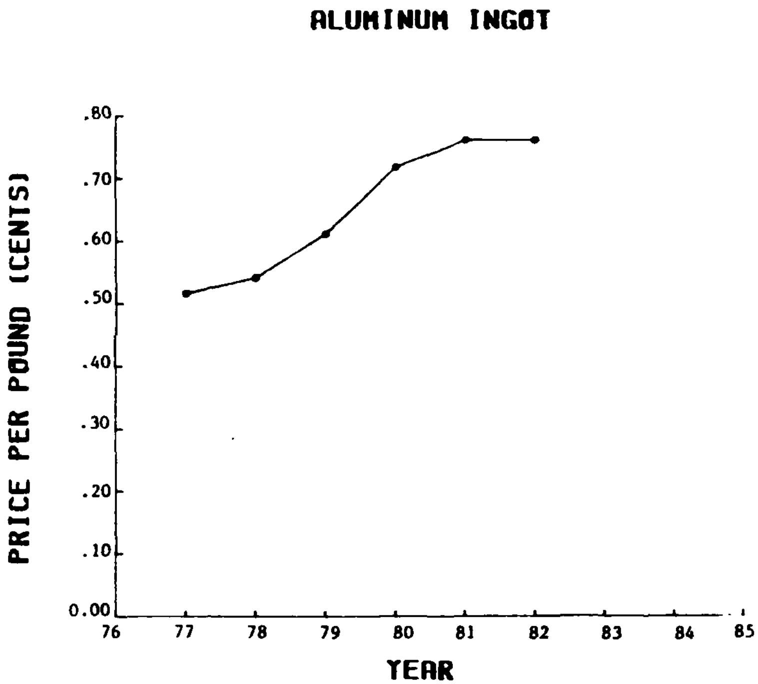


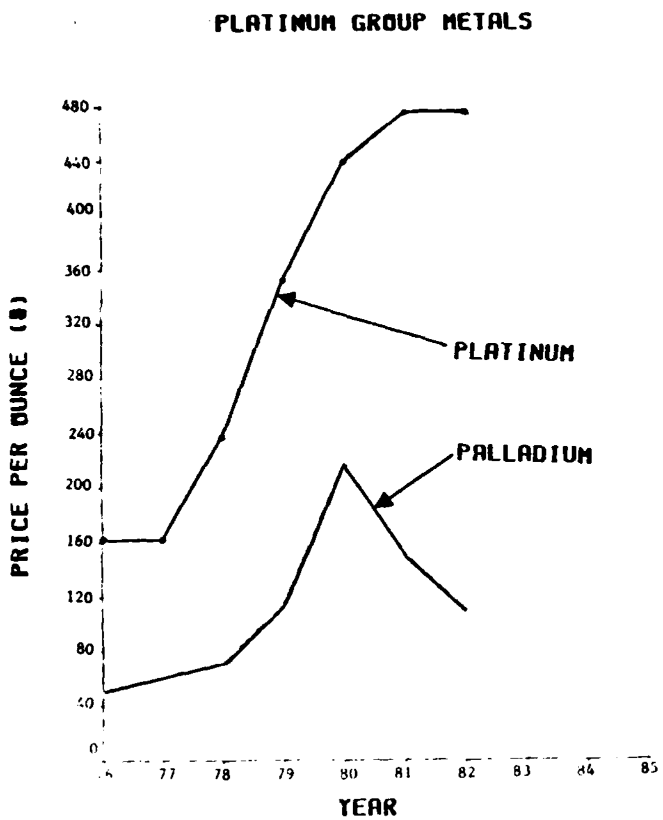
Exhibit III-1. AEROSPACE MATERIALS COST TRENDS
C. CHROMIUM AND ALUMINUM INGOT

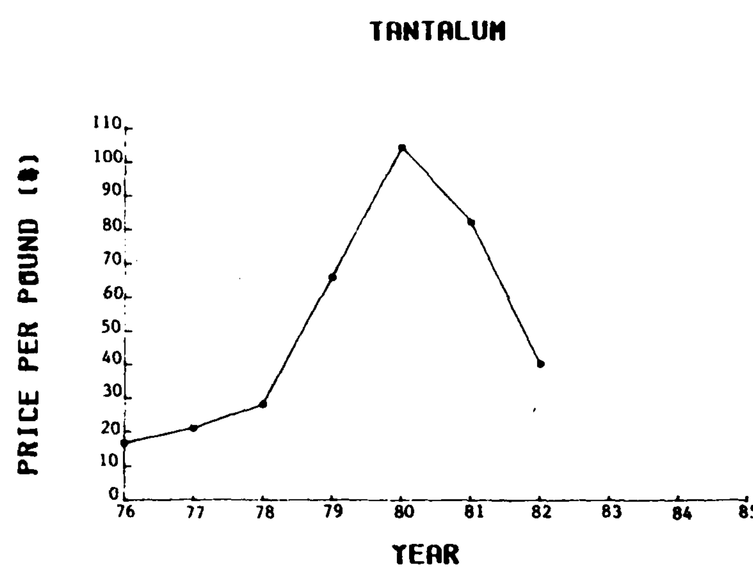
chromium is a very small part of the overall content in most of the applications.

Aluminum is primarily used in airframe structural components, with some limited use in landing gear systems. While aluminum prices have held steady in 1981 and 1982, it should be noted that several of the large aluminum producers are reducing their production capacity. Increase in demand in the automobile industry could cause a change in the cost of aluminum ingot.

Platinum group metals and tantalum (Exhibit III-1D) are used in the production of electronics systems. As can be seen in the graphs, palladium and tantalum follow the same path of peaking in 1980 with a steady decline in prices through 1982. tantalum, in addition to its electronics applications, is also used as an additive to nickel- and cobalt-based alloys used to manufacture engine blades and vanes. The U.S. is completely dependent on foreign sources for its tantalum supply, although efforts are underway to reduce the impact of this dependence. The ever-increasing demand for tantalum comes from not only within the aerospace industry but also from other commercial electronic applications requiring extensive use of tantalum capacitors, such as the radio, T.V. and home computer markets.

The dramatic increases in critical materials costs in recent years, combined with a general dependence on foriegn sources for many of these materials, has caused increased emphasis on developing ways to conserve the use of these materials. The leading techniques for reducing the use of critical materials are:





Source: 1982 Mineral Commodity Summaries

Exhibit III-1. AEROSPACE MATERIALS COST TRENDS
D. PLATINUM GROUP METALS AND TANTALUM

- reduction of raw materials (buy weight) requirements with near-net shape castings;
- substitution of critical materials with less critical materials or new materials (e.g. composites);
- new manufacturing techniques which allow for new applications of existing, less critrical materials (e.. powder metallurgy); and
- recycling of scrap material and worn out parts.

While these techniques can reduce the need given current systems design requirements, new systems such as the B-1 and the MX, with substantial requirements for titanium and cobalt, could produce another demand surge. The Air Force must also compete with other Service programs as well as commercial industry for these and the other limited resources in the aerospace and electronics industries. Finally, the unpredictability of the demand in the defense and commercial aerospace industries make it virtually impossible to effectively plan for surges.

3. Manufacturing and Design Technology

Significant advances in technology, particularly in the electronics industry, can be a mixed blessing for manufacturing costs and leadtimes. On the one hand, improvements in manufacturing technology allow for greater production efficiency, improved quality control and the ability to produce and utilize new high performance materials which have not been possible before. However, the new technologies have contributed to the rapid obsolescence of existing technologies, require substantial new tooling, require new and sometimes rare skills, and contribute to instability in the aerospace supplier base. Circumstances such as the particular technology involved, the type of item produced, the

amount of demand for the item and the competition to produce the item tend to determine the impact on cost and leadtime of the new technology. Some items tend to allow the utilization of new manufacturing technologies (e.g., electronic components), while others do not do so as readily (e.g., electron tubes).

4. Supplier Availability

Another aspect of the overall aerospace industry condition is the status of the supplier base. Studies have indicated that the industry is vulnerable in the second and third tier supplier base. As shown in Exhibit III-2, there are very few qualified suppliers of materials fitting military specifications. Many of these suppliers do not maintain sufficient backlogs of orders to weather economic downturns such as the currently depressed aircraft industry is experiencing. This vulnerability creates the foundation for increased costs and leadtime.

Concern about industry's ability to respond to a surge in demand was part of the outgrowth of the increase in costs and leadtime during the 1979-81 surge. Numerous studies have, in some part, addressed the question of industry capacity and responsiveness.[3/]

3/ Proceedings: U.S. Department of Commerce Public Workshop on Critical Materials Needs in the Aerospace Industry, U.S. Department of Commerce, National Bureau of Standards, July 1981.
Report of the Defense Science Board 1980 Summer Study Panel on Industrial Responsiveness, Office of the Under Secretary of Defense for Research and Engineering, January 1981.
Analysis of Critical Parts and Materials, The Analytical Sciences Corporation, December 1980.
The Air Force Systems Command Statement on the Defense Industrial Base, Headquarters, Air Force Systems Command, November 1980.
Payoff 80: Executive Report - Manufacturing Technology Investment Strategy, Headquarters, Air Force Systems Command, October 1980.
Peacetime Adequacy of the Lower Tiers of the Defense Industrial Base (with appendices), The Rand Corporation, November 1977.

ITEM	No. of Suppliers
Aluminum Plate	2
Aluminm Tubing	2
Titanium Sheet	3
Titanium Wing Skins	2
Titanium Extrusions	1
Aerospace Fasteners	Less than 24 out of hundreds of fastener companies
Air Frame Bearings - Special Ball	1
Needle Bearings	2
Mil. Spec. Qualified Connectors	3
Aircraft Landing Gears	3
Radomes	2
Image Converter Tubes	1
Periscope Lenses	2
Optics Coatings	1

Source: Report of the Defense Science Board 1980 Summer Study Panel on Industrial Responsiveness

Exhibit III-2. STATUS OF AEROSPACE SUPPLIER BASE

These studies have identified a number of reasons contributing to the vulnerability of the material and component supplier base including:

- predominance of small specialized businesses,
- low back-log of orders,
- rigorous environmental restrictions on materials processing,
- scarcity of specialized materials processors,
- Reluctance of small suppliers to contract with the government, and
- Rapidly changing technology base causing transcience in the specialized suppliers.

While efforts have been undertaken to increase the stability of the supplier base, there is still, apparently, the continuing possibility of having a "for want of a nail" situation occur in producing virtually all of the commodities studied.

5. <u>Labor Costs and Availability</u>

Manufacturing costs are substantially influenced by labor costs (as well as materials costs). There has been a generally increasing trend in the wages of production workers in the industries primarily involved in producing BP 1500 items. The actual amount of growth is difficult to calculate since it is not possible, using publicly available sources, to separate the wage trends for defense contracts from commercial contracts. However, generally speaking, inflation for defense systems tends to be higher than for the overall economy.

Listed in Exhibit III-3 are the major industries currently involved in producing defense systems. They are listed

Industry	1979	1982	1987	Defense Output Growth 82-87
Radio & TV Communications	44.8	58.0	62.5	54.2
Aircraft and Missile Engines	42.3	53.5	56.1	32.9
Aircraft and Missile Equipment	43.4	41.2	44.2	34.9
Aircraft	35.0	40.4	46.1	58.7
Nonferrous Forgings	18.0	27.0	29.8	43.3
Electronic Components	12.0	17.0	19.8	44.5
Semiconductors	9.5	12.5	12.5	51.4
Primary Metal Products	6.4	11.9	13.8	48.3
Carbon & Graphite Products	6.1	7.7	9.3	51.4
Brass, Bronze & Copper Castings	5.0	7.5	9.3	51.4
Aluminum Production	5.8	7.5	9.0	51.4
Nonmetallic Mineral Products	6.6	7.5	8.6	45.0
Electron Tubes	8.3	7.3	11.5	105.3
Iron & Steel Forgings	7.9	6.9	7.6	31.4

Source: 1983 U.S. Industrial Outlook

Exhibit III-3. SELECTED INDUSTRIES' DEFENSE MARKET SHARE (PERCENT)

in the order of percentage of total output identified wth systems produced in 1982 for the Department of Defense. Included in this analysis are projections of 1987 defense industrial market shares. The radio are T.V. communications equipment industry dominates this profile due to its role of manufacturer of radar and navigations systems as well as other electronic and avionic systems. The projections for 1987 indicate an increasingly strong relationship in this industry.

The aircraft industry, as reviewed from the several facets shown here, is also heavily influenced by defense demands. This tends to force direct competition with the commercial aircraft industry as can be seen by the proportion of the defense market share. This situation is reinforced by the relationship in the nonferrous forging industry, supplier of critical components to the aerospace industry. The remaining industries tend to show a less dominant role for defense demands, indicating greater dependence on the economy as a whole.

The wage rates for the particular industries are discussed in terms of the particular FSCs to which they relate. The availability of skilled manpower has, in recent years, also been identified as a source of concern and, therefore, a potential factor in costs and leadtimes. Published interviews with representatives from various manufacturers have mentioned this. While unemployment is higher than ever, the types of skills required to produce many of the selected types of equipment are not readily accessible. Retraining efforts are underway; however, they are costly and time consuming.

6. Quantity Ordered

In discussion with manufacturers, a reason frequently given for unit cost increases is uneconomic order quantities. What constitutes an economically impractical order quantity is dependent upon the item in question. However, ordering less than an economically practical quantity can influence the cost and leadtime in a number of ways, particularly in the queue position. While defense prioritization can compensate somewhat in terms of leadtime, order quantities below the minimum desirable amount will usually increase the cost.

B. CONSTRUCTION AND APPLICATION FO COMMODITY GROUPS

As mentioned previously, it was useful in some portions of the analysis to consider FSCs in light of their common characteristics. This was useful for a number of reasons. Frequently, information was found which specifically related to a particular FSC. This information could, however, also be equally applicable to other FSCs, given certain characteristics they all might have in common. This was found to be the case, particularly with respect to materials usage and technology, both design and manufacturing.

The three commodity groups developed based on our research are shown in Exhibit III-4. These groups are:

- Engines, containing FSCs 2840 and 2915 - Gas Turbines & Jet Engines, Aircraft; and Components and Engine Fuel System Components, Aircraft;
- Structures, containing FSCs 1560 and 1620 - Airframe Structural Components and Aircraft Landing Gears; and

Engines	2840 - Gas Turbines & Jet Engines, Aircraft; and Components
	2915 - Engine Fuel System Components, Aircraft
Structures	1560 - Airframe Structural Components
	1620 - Aircraft Landing Gears
Electronics	5865 - Electronic Countermeasures, Counter-Countermeasures, and Quick Reaction Capability Equipment
	6605 - Navigation Instruments
	1270 - Aircraft Gunnery Fire Control Systems
	1280 - Aircraft Bombing Fire Control Systems
	5841 - Radar Equipment, Airborne
	5960 - Electron Tubes & Associated Hardware

Exhibit III-4. COMMODITY GROUPINGS

- Electronics, containing FSCs 5865, 6605, 1270, 1280, 5841, and 5960 - Electronic Countermeasures, Counter-Countermeasures and Quick Reaction Capability Equipment; Navigation Instruments, Aircraft Gunnery and Bombing Fire Control Systems, Airborne Radar Equipment, and Electron Tubes & Associated Hardware.

These groups were used to varying degrees based on the amount of information obtained in the research and the extent to which common characteristics influenced projections for costs and leadtimes.

The most significant use of the commodity group concept was with the electronics FSCs. Very little FSC-specific information was identified for the first five FSCs in this group, the only exception being the detailed information obtained on electron tubes. It is believed that, given this dearth of specific information, as well as the similarity of the types of materials and manufacturing technology used in these systems, that grouping them in this manner was appropriate.

Listed in Exhibit III-5 are the critical materials used in the design of the systems in the FSCs by commodity groups. Individual systems may or may not contain all of the materials identified with the commodity group, but generally these materials are associated with these types of systems. In this application, the term critical is used to indicate not only those materials considered to be strategic because of supply repercussions or costs but also those materials which are necessary in the design of the systems. Readily accessible materials such as steel alloys, while necessary to some of the systems, have, however, not been included in this list, while costly materials

MATERIALS \ APPLICATIONS	ENGINES	STRUCTURES	ELECTRONICS
TITANIUM	X	X	
TANTALUM	X	X	X
CHROMIUM	X		
COBALT	X	X	X
NICKEL	X	X	
ALUMINUM	X	X	
COLUMBIUM	X	X	
STEEL		X	
GOLD	X		X
SILVER			X
PLATINUM GROUP			X
CERAMICS	X		X
BORON		X	

Exhibit III-5. CRITICAL MATERIALS REQUIREMENTS BY COMMODITY GROUPING

such as gold, silver and platinum group metals have been included. Specific aspects of the impact of these materials are considered in more detail in the discussion of the commodity-specific cost trends.

Having reviewed this general information on the aerospace industry, the commodity-specific analysis and factors are discussed next.

IV. COMMODITY-SPECIFIC COST AND LEADTIME FACTORS

The following topics are discussed in this section:

- the responsiveness of the manufacturers to the data request,
- the general cost trends of the selected BP 1500 FSCs, and
- the general leadtime trends of the selected BP 1500 FSCs.

One of the primary purposes of this research was the development of a set of factors to be used in refining the BP 1500 commodity costs and leadtimes. These factors were intended to be used in conjunction with the development of the LMI/AAM estimate for the FY85 POM.

Specific cost and leadtime trends were studied for the selected commodities and, to the degree possible, these have been quantified. Separate cost and leadtime factors have been developed for each commodity or, as in the case of the five electronics-type FSCs, for the commodity group. Given the significantly different nature of the impact on requirements of changes in costs and changes in leadtime of an item, it was considered more appropriate to keep the trends separate.

A. MANUFACTURER RESPONSIVENESS

The major factor influencing the specificity of the cost and leadtime factors developed in this study was the amount of detailed data available and accessible from the data sources. As discussed in Section II, emphasis was placed on obtaining as much detail as possible from the actual producers of the items.

While virtually all of the manufacturers expressed a sincere interest in cooperating, the timeframe in which a response was needed, combined with the potentially extensive research required to develop a response, tended to limit their ability to contribute to the research. Exhibit IV-1 summarizes the general responsiveness of the manufacturers to the data request.

As can be seen, frequently "General Information" is indicated as the manufacturer's response. This is to indicate that, while specific details concerning all of the questions in the data request may not have been provided, information on either general industry conditions or on particular systems the manufacturer produces was obtained. These contributions are noted when appropriate in the factor discussions.

The term "Specific Information" refers to more comprehensive presentations of information addressing particular aspects of interest, such as critical materials applications, provided in response to our request. "Detailed Information" refers to the two manufacturers who provided detailed and specific responses to the data request. In the case of Pratt & Whitney Aircraft, substantial amounts of supporting information were also provided.

There are instances where the term "Will Not Respond" is listed. In these cases, the manufacturer has indicated that the magnitude of the data requested and the resources required to formulate an adequate response prohibit their cooperation at this time. They would, however, be willing to respond if compensated for their efforts. (All recipients of the data request were informed that cooperation was completely voluntary.) In

Manufacturers	Response
Bendix Corporation	General Information
Boeing Military Aircraft Corporation	Still Developng Response
General Dynamics Corporation	Will Not Respond
General Electric Corporation	General Information
Grumman Aerospace Corporation	Specific Information
Honeywell, Inc.	General Information
Lockheed Corporation	Still Developing Response
McDonnell-Douglas Corporation	Will Not Respond
Menasco, Inc.	General Information
Pratt & Whitney Aircraft	Detailed Information
Texas Instruments, Inc.	Specific Information
Varian Associates	Detailed Information
Westinghouse Electric Corporation	Will Not Respond
Wyman-Gordon Company	Still Developing Response

Exhibit IV-1. MANUFACTURER RESPONSIVENESS
AS OF 11 MARCH 1983

some cases, these manufacturers are noted as sources of data used in the analysis. In those cases, data was obtained from published information.

Finally, in several cases, manufacturers did not have an opportunity to respond to the data request in time for inclusion in this report. These cases are indicated by the term "Still Developing Response."

The other major sources of data were the publicly accessible published reports, studies and periodicals. As previously discussed, the regularly generated reports (e.g., Producer Prices and Price Index, U.S. Industrial Outlook, etc.) tended to provide more general kinds of information, primarily because they are organized around the Standard Industrial Classification (SIC) codes. The defense portion of the market in the SIC is only rarely discussed here (as in Exhibit III-3).

To the degree possible, cost and leadtime trends for each commodity/commodity group have been compiled using all of the data sources reasonably available. These factors or trends are presented in the following sections.

B. GENERAL COST TRENDS FOR SELECTED BP 1500 FSCs

In constructing the FSC cost trends, it was not possible in all cases to develop quantified estimates for the near term (1985) or long term (1989). In these instances, qualitative data has been summarized and used. In all cases, the basic reasons supporting the projected tend are presented and discussed. Exhibit IV-2 summarizes the general cost trends for the selected

FSC	Title	Near-Term Cost Trend	Long-Term Cost Trend
2840	Gas Turbines & Jet Engines, Aircraft; and Components	F-100 Engines: +12% Other PWA Engines: +12-15%	Increasing Increasing
2915	Engine Fuel System Components	Stable at 1982 Levels	Stable
1560	Airframe Structural Components	Increasing	Increasing
1620	Aircraft Landing Gears	Insufficient Data	Insufficient Data
5865	Electronic Countermeasures, etc.		
6605	Navigation Instruments		
1270	Aircraft Gunnery Fire Control Components	Increasing	Increasing
1280	Aircraft Bombing Fire Control Components		
5841	Radar Equipment, Airborne		
5960	Electron Tubes & Associated Hardware	+10-34%	Increasing

Exhibit IV-2. BP 1500 COMMODITY-SPECIFIC GENERAL COST TRENDS

FSCs. As can be seen, five of the FSCs have been handled collectively as electronics systems. The reasons for this will be discussed in the cost trend discussions below.

1. Gas Turbines & Jet Engines, Aircraft; and Components (FSC 2840)

The single largest FSC represented in the BP 1500 requirements is Gas Turbines & Jet Engines, Aircraft; and Components. There are four major manufacturers of engines or engine spare parts currently used on fixed wing aircraft in the Air Force: Pratt & Whitney Aircraft, General Electric, Detroit Diesel Allison, and AiResearch. Emphasis was placed on contacting Pratt & Whitney and General Electric, considered by the Air Force to be the dominant manufacturers of BP 1500 engines. As previously mentioned, Pratt & Whitney provided a detailed response to our data request, data which formed the basis for this analysis. Two groups within General Electric were contacted in our survey: the Aircraft Engine Division and the Aerospace Division, in which systems in the other FSCs are produced. The Aircraft Engine Division could provide only general information on engine costs and leadtimes due to internal resource constraints on developing an adequate response. In addition to the Pratt & Whitney data, information pertaining to the overall aircraft engine industry was also obtained from Business Week and the 1982 and 1983 U.S. Industrial Outlook. The percentage increases for the Pratt & Whitney Aircraft (PWA) F-100 engines and the older PWA engines are shown in Exhibit IV-2 as a percentage increase per year.

The following reasons were identified for the projected cost trends:

- Out-of-Production Engines:
  - Lack of required tooling,
  - Older/obsolete manufacturing techniques,
  - Unavailable secondary suppliers, and
  - Requirement for older materials;
- Materials Requirements:
  - Two-year lag time in materials costs reimbursement to the manufacturer,
  - Current downward trend in critical materials (titanium, aluminm, cobalt; not expected to go as low as 1978 prices), and
  - Increased use of materials conservation (near net-shape casting, scrap recycling, substitution, etc.); and
- Labor Costs:
  - Shortage of skilled manpower in primary, secondary and third tier manufacturers,
  - Negotiation of new union contracts (steel, aluminum and aerospace), and
  - Production worker in Aircraft Engines and Engine Parts (SIC 3724) hourly wage compound annual rate of growth between 1972 and 1982 was 9.4%.

Of particular importance in projecting cost (and lead-time) trends for military aircraft engines are the impacts due to materials requirements, manuacturing technology and performance specifications. The materials required in military engines are usually of a much higher quality than other applications of the same material. Prices for engine-grade titanium and cobalt are at the top of the range of prices generally quoted in minerals markets. The leadtime in the production process, quoted as two years, means that the prices currently being paid for these materials will show up in the 1985 time frame. The most recent trends in the critical aerospace materials were discussed in Section II. Generally,

materials account for approximately 60 percent of the aircraft engine costs, with labor accounting for the remaining 40 percent. However, it is possible that the mix for spares may be different.

As noted earlier, the production status of an engine has significant impact on the cost of spares. In most cases, costs of spares for an out-of-production system cannot be estimated. Generally, a Pratt & Whitney engine is considered out of production if an order for it has not been filled in two years.

While labor may represent a slightly lower proportion of total engine cost in some engine types (as little as 25%), the general trends are toward increasing labor costs.

2. Engine Fuel System Components (FSC 2915)

Two manufacturers of engine fuel systems were identified: Bendix Corporation and Hamilton Standard. Efforts to contact Hamilton Standard were not successful; however, general information on the subject has been obtained from Bendix Corporation, and has been used in constructing these factors. Without knowing the specific data currently being used to develop the requirements estimates for engine fuel systems, it is not possible to quote an exact figure. For systems which Bendix produces, the information should be accurate because they provide multi-year price estimates and annually update the information. In addition, while engine fuel systems are as unique as the engines with which they interact, they are, according to Bendix, not as technologically sophisticated, which seems to allow for more overall stability in production. Rapidly changing manufacturing

technology may influence costs and leadtimes. However, the designs themselves are apparently so closely tied to specific engine designs that they are also driven by the prolonged and exacting engine certification process.

Bendix provided the following general reasons that costs are expected to be stable in the near and long terms:

- Use of catalog arrangement with the Air Force;
- Costs based on three-year cost estimate;
- Very few out-of-production systems;
- Lack of requirement for critical/exotic materials (e.g., titanium, beryllium, etc.); and
- Not heavily dependent on other suppliers.

3. Airframe Structural Components (FSC 1560)

For this FSC, the following aircraft manufacturers were contacted: Boeing Military Aircraft Company, General Dynamics Corporation, Lockheed Corporation, and McDonnell-Douglas Corporation. Of these, General Dynamics and McDonnell-Douglas Corporation could not provide assistance at this time, and Boeing and Lockheed were still in the process of responding at the time this report was written. For these reasons, alternative sources have been used to develop this factor, including the annual Mineral Commodities Summaries, and the Department of Commerce study of Critical Materials Requirements in the Aerospace Industry. Additional information received from Grumman Aerospace has supported this analysis concerning the overall trends in the aerospace industry. As with other FSCs, trends in materials costs and labor wage rates have been used as indicators

of general trends. The following reasons were identified as influencing the general increasing trend in this FSC:

- Competition with other Service requirements, commercial aircraft industry, and non-aerospace applications;
- Stable near-term aluminum costs, questionable surge capability in the aluminum industry;
- Increased use of new/exotic materials (e.g., graphite and fiber composites, superalloys) and manufacturing techniques (e.g., weldbonding, rapid solidification, isothermal forging, etc.) with initial investment costs (e.g., A-10 structural members of composite materials); and
- Production worker hourly wage in Aircraft (SIC 3721) and Aircraft Equipment (SIC 3728) compound annual rate of growth between 1972 and 1982 were 9.3% and 9.0% respectively.

4. Aircraft Landing Gears (FSC 1620)

The two manufacturers of aircraft landing gears contacted in this study are Menasco, Inc. and Bendix Corporation. While both of these organizations received the data request, they had not completed developing their responses by the time this report was written. While MCR has some information on the materials composition of these system, steel alloys primarily, it is not considered sufficient to allow construction of cost or leadtime factors for this FSC.

5. Electronics Systems (FSCs 5865, 6605, 1270, 1280 and 5841)

As discussed previously, the FSCs representing Electronic Countermeasures, Counter-Countermeasures, and Quick Reaction Capability Equipment, Navigation Instruments, Aircraft Gunnery and Bombing Fire Control Systems, and

Airborne Radar Equipment have been collectively analyzed. Electron tubes, while considered for some purposes as part of the electronics systems group, are discussed separately in the cost and leadtime discussions. The variety of possible systems and manufacturers, and the lack of specific detail on many of the systems, did not facilitate the examination and development of individual trends. Attempts to obtain information from manfacturers of these types of systems have produced only general information. For these reasons, MCR had to rely on the published sources:

- 1983 U.S. Industrial Outlook,
- Producer Prices and Price Index, and
- Report of the Defense Science Board 1980 Summer Study Panel on Industrial Responsiveness.

The commonality of the materials and components used in producing these types of systems allowed for the construction of only general trends. The following reasons are given for MCR's belief in the generally increasing trends in costs for these types of systems:

- Mixed price trends of electronic components, with semiconductors dropping substantially, but most of remaining components increasing slightly;
- Overall trends in radio & TV communication equipment industry (SIC 3662), manufacturers of navigation, radar, electronic countermeasures and fire control systems:
    - 60% increase in Bureau of Industrial Economics product price index between 1972-82, and
    - Military procurements account for 47% of industry shipments;

- Competition for components with radio, TV, arcade game, small computers markets;
- Increasingly efficient manufacturing techniques countered by rapid obsolescence of technology;
- Materials cost fluctuations (e.g., gold, tantalum, etc.) reflecting lack of stability in materials prices;
- Few suppliers available for older technology systems - reconstruction of technology costly;
- Raidly shifting supplier base, rapid replacement of low volume product lines;
- Heavy dependence of semiconductor market on foreign trade; and
- Increases in labor costs, specifically:
    - Radio & TV communications equipment production workers average hourly wage had a compound annual rate of growth between 1972 and 1982 of 8.2%, and
    - Electronic components production workers hourly wages increased by an annual compound rate of 8.1% between 1972 and 1982.

Analysis has concentrated on general trends in materials costs, components prices, manufacturing technology, other sources of demand/competition, and labor wage rates. A dominant force in the cost trends in the electroncis industry is its close relationship to the radio and T.V. communication equipment industry, a major user of electronic components, as well as being the manufacturer of most of the systems in these FSCs. The rate at which technology is advancing in this sector, both design and maufacturing technology, make it difficult to project specific near-term, let alone long-term, trends. While manufacturing techniques are causing a rapid decrease in the price of components such as semiconductors, the increased use of materials

such as tantalum could substantially increase the price, as happened in the surge. Technology replacement is occurring so quickly that the supplier base cannot stabilize. Suppliers are frequently abandoning less productive low-volume, older technology product lines with the result that it may be extremely difficult to replace parts and components on many current technology systems in the future.

Finally, labor wage rates are continuing to increase, although not at the rate of some of the other sectors of the aerospace industry. Current moves to retrain workers from other industries, such as the automobile industry, as workers in the electronics industry may have a mitigating effect on the upward trend in labor wages.

Listed in Exhibit IV-3 are the cost trends for a selection of materials, components and assemblies used in electronic systems. These trends have been calculated using data from the Producer Prices and Price Index (PPI) for the period December 1980 to November 1982.

6. Electron Tubes and Associated Hardware (FSC 5960)

The major source for information on electron tubes was Varian Associates, a major supplier of electron and traveling wave tubes to the Air Force. Attempts have been made to collect additional data on this industry (i.e., Producer Prices and Price Index - SIC 1178). However, specific information on electron tubes is largely submerged in discussion of the overall electronics industry. Changes in technology are, in many applications,

Industry/Product	Near-Term PPI Projection (Annual % Change)
Primary Copper	-2.4
Gold, Unalloyed	-2.6
Silver, Unalloyed	17.3
Semiconductors/Related Devices	-4.1
Electronic Capacitors	-2.5
Resistors for Electronic Application	1.7
Electronic Coils, Transformers, Other Inductors	2.4
Connectors for Electronic Application	3.0
Electronic Components, N.E.C.	1.8
Receiving Type Electron Tubes	34.5
Power, Transmitter, Spec. Purp. Tubes	10.5
Capacitors	-4.0
Resistors for Electric Applications	1.9
Relays	8.8
Switches, Mechanical (Electronic Application)	0.9
Antennas	11.4
Connectors	2.3
Parts for Electronic Components	20.2
Filters, Crystals, and Transducers	0.3
Diodes	-1.1
Thyristors	1.3
Transistors	0.0
Optoelectronic Devices	-0.4
Digital Bi-Polar ICs	-7.8
Digital MOS ICs	-6.2
Linear ICs	0.5
Hybird ICs	4.3
Other Semiconductor Devices and Parts	-38.6
Printed Circuits and Cable Assemblies	-0.6
Static Power, Pulse and Frequency Connectors	2.0
Electronic Transformers and Coils	2.1
MW Components, Extubes, Semiconductors, Antennas	0.0
Complex Component Assembly, Packs, Modules	0.0

Source: Producer Prices and Price Index

Exxhibit IV-3. SELECTED COMPONENT COST TRENDS

shifting from use of electorn tubes to solid state components. As of now, there are only two applications in which solid state components cannot replace electron tubes: cathode ray tubes, primarily used in computer terminals, and high power radio and radar transmitters. As technology advances, there will be fewer and fewer suppliers of "older" technology, spares for which will assuredly be much more expensive than they currently are.

The following are the reasons for MCR's estimated cost trends in this FSC:

- Low estimate of 10 percent is based on Varian Associates' average cost increase history;
- High estimate of 34.5 percent based on analysis of near-term producer price index for receiving electron tubes;
- Most significant driver of cost - in-house manufacturing techniques - (lower costs for in-production older technology);
- Potentially high materials costs due to limited supplier base, high cost materials (i.e., gold brazing), small quantity; however, the overall impact of material cost is generally low compared to manufacturing cost;
- Start-up cost approximately 10% of order value; and
- Few opportunities to replace required materials and modify manufacturing techniques.

C. GENERAL LEADTIME TRENDS FOR SELECTED BP1500 FSCs

The following are the factors MCR has developed as a result of information gathered on commodity manufacturing leadtimes. Within the BP 1500 requirements estimating process, leadtime can be referred to in a variety of ways: administrative leadtime, production leadtime, and procurement leadtime. In

our research, we have focused on collecting information on production leadtime, that is, the time from receipt of an order by the manufacturer to shipment of substantial quantities. Unfortunately, it has been difficult to obtain specific data on actual production leadtime. This is largely due to the fact that production leadtime is generally composed of two elements: queue time, which, for the purposes of this study, also includes the time it requires to obtain long leadtime materials such as large castings and forgings; and fabrication leadtime, which relates to the amount of time it takes the manufacturer to fabricate and assemble the parts into the required item. While long leadtime material data was often available, there was insufficient time to obtain specific details from the manufacturers on fabrication time. In addition, while the differences between a total system and spares were said by manufacturers to not influence the cost of the spares for an item, it is unclear if assembly time becomes a factor in distinguishing the impact between complete systems and spares. The general leadtime trends for the selected BP 1500 FSCs are summarized in Exhibit IV-4, and are discussed in more detail below.

1. <u>Gas Turbines & Jet Engines, Aircraft; and Components (FSC 2840)</u>

As with manufacturing costs, the manufacturing leadtime factor for Gas Turbines and Jet Engines is largely based on data received from Pratt & Whitney Aircraft and <u>Business Week</u>. Pratt & Whitney supplies an update of leadtime data on a quarterly basis to the ALCs. Engine leadtime is driven by the amount of

FSC	Title	Near-Term Leadtime Trend	Long-Term Leadtime Trend
2840	Gas Turbines & Jet Engines, Aircraft; and Components	Stable at 1982 Duration (Approx. 2 years)	Increasing
2415	Engine Fuel System Components	Stable at 1982 Duration	Stable
1560	Airframe Structural Components	Stable at 1982 Duration	Stable
1620	Aircraft Landing Gears	Insufficient Data	Insufficient Data
5865	Electronic Countermeasures, etc.		
6605	Navigation Instruments		
1270	Aircraft Gunnery Fire Control Components	64 Weeks/Stable	Stable
1280	Aircraft Bombing Fire Control Components		
5841	Radar Equipment, Airborne		
5960	Electron Tubes & Associated Hardware	Standard: 8-10 Months State of the Art: 12-18 Months	Same Same

Exhibit IV-4. BP 1500 COMMODITY-SPECIFIC GENERAL LEADTIME TRENDS

time required to obtain titanium forgings, a necessary component which Pratt & Whitney does not keep in inventory. The following summarize the reasons for the projected leadtime trends:

- Reconstruction of out-of-production engine tooling, materials, etc.;
- Critical leadtime influence of Titanium forgings - longest leadtime item with high minimum time;
- Depressed aerospace industry - reduced demand for critical materials;
- Downward response to 1978-81 surge - 1978-81 leadtimes due to increase in commercial aircraft orders combined with shortage in raw and processed critical materials and reduced imports; and
- Projected turnaround in economy expected to produce increase commercial aircraft industry demand.

2. Engine Fuel System Components (FSC 2915)

As noted in the cost trend analysis of engine fuel systems, the main source of data has been Bendix Corporation. As part of their catalog arrangement, they provide information on leadtimes. For this reason, while not knowing the specific data in the BP 1500 requirements system, it is expected to be as current as possible for Bendix fuel systems. The following reasons were given for the projected stable leadtime trends:

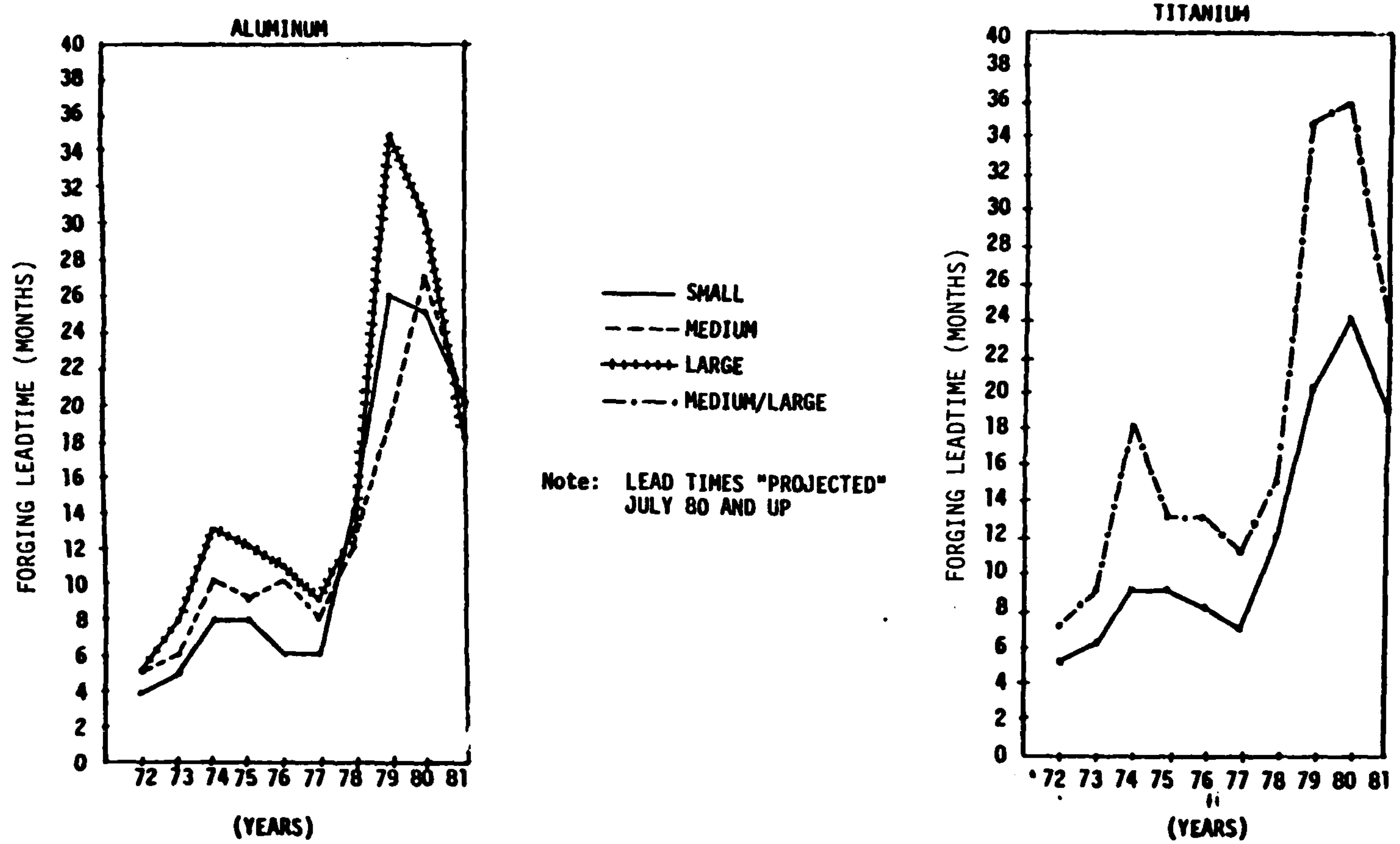
- Use of long-term master schedule planning by Bendix;
- Lack of reliance on critical materials;
- Rapidly changing manufacturing technology allows for reduction in leadtime; and
- Design modification tied to aircraft engine design and the rigorous certification process.

3. Airframe Structural Components (FSC 1560)

The analysis of airframe structural component leadtime has necessarily been very general due to the lack of specific data from manufacturers. MCR's estimated trends are based on analysis of information contained in Data Resources, Inc.'s Defense Economic Research Report, or unfilled and new orders for aircraft, missiles and parts, general decreases in material production leadtimes, and the analysis of the generally depressed aerospace industry from the 1982 and 1983 U.S. Industrial Outlook. The following are the major reasons for the projected leadtime trends in this FSC:

- Decreases in recent material leadtimes; unused aluminum production capacity;
- Depressed commercial aerospace, automobile and building industries;
- Fabrication requirements for out-of-production and older aircraft (counter effect to downward trend); and
- Data Resources, Inc. estimates of unfilled and new orders for aircraft, missiles and parts, both increased over 1981 (counter effect to downward trend).

Depicted in Exhibit IV-5 are the leadtime histories for aluminum and titanium forgings as depicted in data collected by McDonnell Aircraft Company. Additional data developed by Grumman Aerospace, and General Dynamics on leadtimes for aluminm and titanium castings and forgings supports these charts. These three studies are contained in the Proceedings--Public Workshop on Critical Materials Needs in the Aerospace Industry. In addition, an AFBRMC study performed by The Analytical Sciences Corporation entitled Analysis of Critical Parts and Materials,



Source: "Definition of Aerospace Industry Materials Needs," McDonnell Aircraft Company, 2 February 1981.

Exhibit IV-5. FORGING LEADTIME (MONTHS)

December 1980, supports the increasing trend, although generally more extended ranges are indicated. In all of these studies, the major factors cited as contributing to these leadtime increases were limited industrial capacity and raw materials shortages.

More current information has been requested from Wyman-Gordon, the major supplier of aerospace castings and forgings. This information had not been received at the time this report was written. There is a general downward trend in these leadtimes from the 1979-81 peak.

4. <u>Aircraft Landing Gears (FSC 1620)</u>

At the time this report was written, MCR had not obtained specific enough information from the manufacturers of aircraft landing gears to construct a general trend in leadtimes for this commodity.

5. <u>Electronic Systems (FSCs 5865, 6605, 1270, 1280 & 5841)</u>

Information on the leadtimes associated with the FSCs collectively considered as electronics systems (excluding FSC 5960, electron tubes and associated hardware) has been collected from a variety of sources. Texas Instruments, Inc. provided specific information, and additional information was obtained from a Westinghouse Electric Corporation survey and the <u>Defense Science Board 1980 Summer Study Panel on Industrial Responsiveness</u>.

General indications are that leadtimes are expected to be stable, although the dynamic nature of the electronics industry makes specific projections difficult. The following summarizes the major reasons for the projected leadtime trends in the electronics systems:

- Westinghouse survey of electronics manufacturers - 24 month history;
- Rapid technology improvements in manufacture of electronics components;
- Stable base of prime manufacturers (radio & TV equipment manufacturers); and
- Dominant role of military procurement in industry.

In an effort to provide additional detail which may be of use in interpreting information already in the data base, MCR has compiled a list of component leadtimes which we believe to be current. This list is shown in Exhibit IV-6.

6. Electron Tubes and Associated Hardware (FSC 5960)

Information on leadtimes for electron tubes has been obtained from Varian Associates. As noted, the significant driver for leadtime is materials, with the small ordering quantities influencing the amount of time required to obtain materials and components. The following are the major reasons identified for the leadtime tends in this FSC:

- Long Lead Components: Magnets, Ceramics and cathodes (6-8 months historically);
- Significant driver - small quantities of materials, few suppliers; and
- Test equipment leadtime approximately 12 months for state-of-the-art tube designs.

COMPONENTS	LEADTIME (WEEKS)
Bearings	
- Ball	32-92
- Hi Temp (600° F+)	No Quote
Microwave Components (General)	36
Electron & Traveling Wave Tubes	24-48
Optics Materials	8-12
Capacitors	16-24
Resistors	12-20
Connectors	24-12
Semiconductors	12-28
Castings (Electronic)	
- Aluminum	12-20
- Magnesium	20
- Steel	24
- Die	16
Wire and Cable	28
Forgings (Electronic)	28

1982 Westinghouse Electric Corporation survey showed average production leadtime for electronics systems of approximately 64 weeks.

Source: Texas Instruments, Inc., Pratt & Whitney Aircraft; McDonnell-Douglas

Exhibit IV-6. SELECTED COMPONENT LEADTIMES

While the cost and leadtime trends represented in the preceeding discussion are, in some cases, only qualitative in nature, MCR considers them the most reasonable approximation of forseeable trends based on the information available.

V. CONCLUSIONS AND RECOMMENDATIONS

Based on MCR's research of the cost and leadtime trends for the selected BP 1500 FSCs, the following conclusions and recommendations have been reached.

A. CONCLUSIONS

Summarizing the factor information beyond the level presented in this study could lead to false generalizations concerning cost and leadtime trends. Caution should be used in attempting to make any general statements concerning overall cost and leadtime trends.

Manufacturers have additional information; however, it will take a more concerted effort than was possible in this study to obtain it. Potentially useful information is provided by the manufacturers as proposal support documentation. Analysis of the DD 633 forms the manufacturers submit in proposals would prove useful in determining the trends in growth of the cost elements. This information may not be adequately represented in the BP 1500 data systems or supporting analyses.

Information obtained from second order sources (i.e., reports, studies, etc.) is primarily useful for analyzing overall industry trends and cost and leadtime drivers. This is primarily because much of the analysis does not specifically address the defense portion of the aerospace and electronics industries. Special studies on industrial responsiveness and other aspects of the

aerospace industry are of great help in understanding cost and leadtime drivers, but are usually one-time-only studies, and are quickly out of date.

A variety of sources of useful data exists outside of the regular BP 1500 requirements analysis process. Many of these may not be adequately represented in the process. However, it is quite possible they could provide some assistance in attempting to update cost and leadtime estimates for the difficult out-of-production items.

B. RECOMMENDATIONS

MCR's analysis and conclusions suggest the following recommendations.

USAF/LEX and AFLC should pursue manufacturers as sources of additional data. In order to maximize the effectiveness of such an effort, the data to be requested and the specific systems of interest should be identified beforehand. Also, efforts should be made to determine if potentially useful data are already possessed by other groups within the Air Force.

In conjunction with this effort, the Air Force should investigate the use of procurement data, specifically the data provided as supporting documentation for aircraft spares production proposals (e.g., on DD 633 forms). The structure of the BP 1500 data systems severely restricts the amount of acquisition data maintained for each item. There may be much more information which is normally provided and not used in development of BP 1500 requirements forecasts.

Finally, there is still a need for a commodity-specific parametric estimating relationship. As a minimum, the following analyses should be undertaken:

- analysis of the relative proportion of cost elements to the total cost for different commodities (i.e., materials, direct and indirect labor, overhead, G&A, fee, etc.);
- analysis of the detailed trends in commodity cost and leadtime drivers; and
- evaluation of the levels of analytical detail appropriate for AFLC analysis and USAF/LEX analysis (e.g., item-specific analysis vs. commodity-specific analysis).

APPENDIX A

SUMMARY OF AFLC PHASE IV RESEARCH

SUMMARY OF AFLC PHASE IV RESEARCH

The research documented in this report represents MCR's efforts in response to tasking developed and directed by USAF/LEX. This tasking was a revision of MCR's original Phase IV tasking in support of AFLC/LOR. This appendix summarizes MCR's efforts in support of the original Phase IV tasking performed during the period of 18 July to 31 September 1982. Four main tasks comprised the original MCR Phase IV tasking:

Task 1 - Research data availability,

Task 2 - Develop additional data sources,

Task 3 - Refine the factor components list for each factor, and

Task 4 - Factor computation.

As noted in the introduction, this tasking was designed to continue the analysis begun with the Phase I-III tasking completed by MCR in May 1982. Phase II was designed to determine the feasibility of actually developing values for the Program Changes (R_1), Inventory Status (R_3), and Design/Engineerng (R_4) factors. Exhibit A-1 shows the original schedule for this tasking, covering the nine-month period 1 August 1982 through 30 April 1983.

As originally planned, Task 1, Research data availability, would involve the first three months. Task 1 was composed of two subtasks:

1.1 - Determine factor levels, and

1.2 - Identify data sources.

The identification of data sources was the primary concern of this task. Potential sources of data included the D041 system,

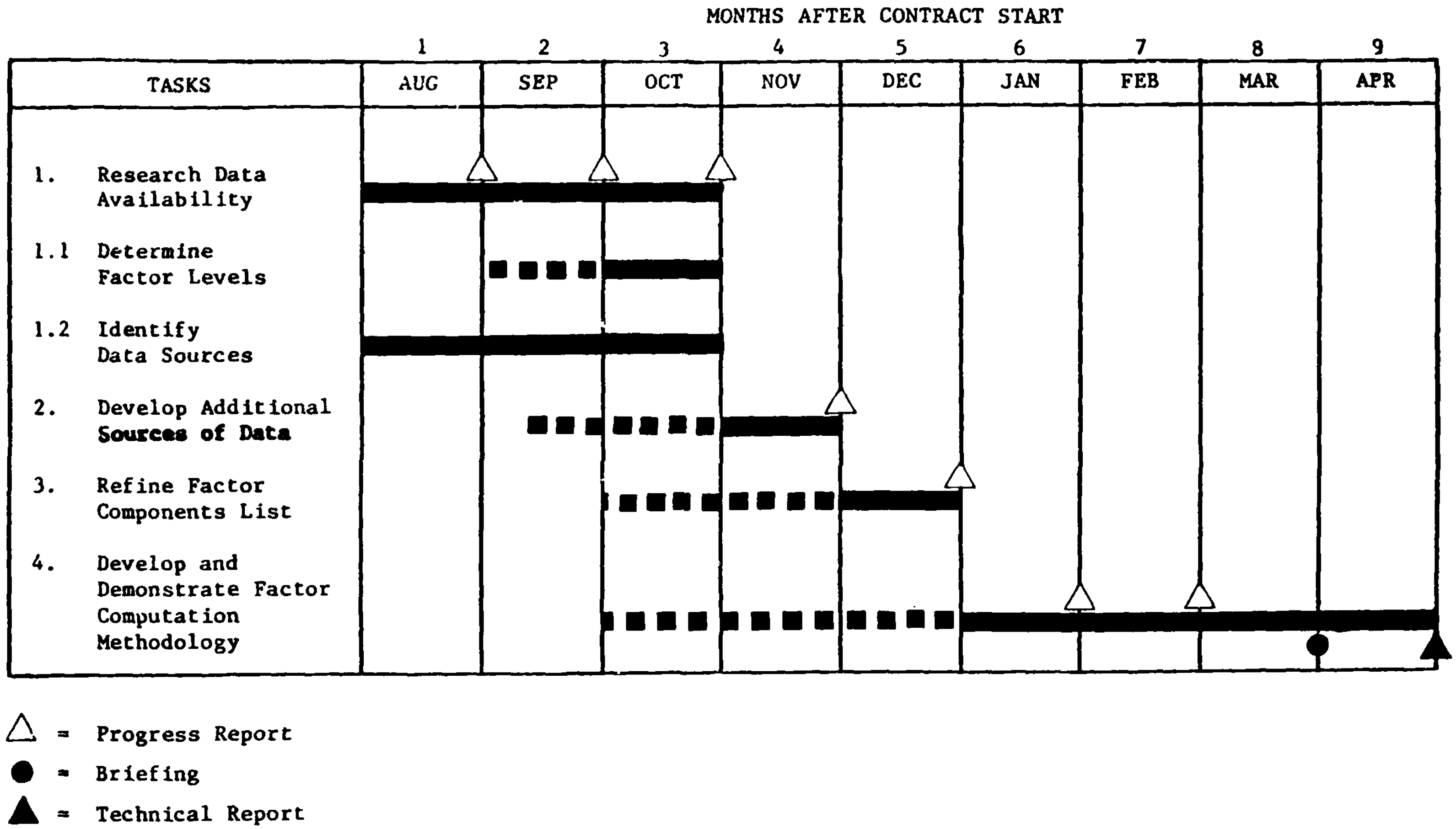


Exhibit A-1. ORIGINAL PHASE IV SCHEDULE

Air Force planning documents, and other government and industry studies and reports. The Air Logistics Centers (ALC) were also considered as potentially significant sources of data.

At the request of AFLC/LORA, MCR initiated the Phase IV effort before actual initiation of the contract in order to attend the Material Management Review at the Oklahoma City ALC. This was considered desirable as an opportunity to:

- contact groups who could provide detailed understanding of the historical reasons why requirements have changed;
- determine if data was available at the ALC level; and
- begin to determine the most appropriate levels at which to develop the factors (i.e., M/D, item, etc.).

This trip took place beween 18 and 23 July 1982, the results of which were documented in a trip report dated 3 August 1982. Potential sources of data for selected aircraft types were identified at that time. A subsequent request for data was submitted to several systems managers; however, no responses were received before the tasking redirection took place. These sources were not considered useful for the Revised Phase IV tasking and were not pursued. Efforts to identify data within the D041 system were also not pursued because of the emphasis on non-Air Force sources in the revised tasking.

The other significant portion of the original Phase IV tasking involved identification of potentially useful reports and studies. Several bibliographic searches were conducted and used in the revised tasking. Wherever possible, the results of the original research have been incorporated in the research requirements of the

revised tasking. Specific details on the research activities for both the original and revised Phase IV tasking have been documented in the monthly and bi-weekly progress reports submitted to AFBRMC, AFLC/LOR and USAF/LEX.

APPENDIX B

DATA SOURCES

DATA SOURCES

The following data sources have been used in this research in addition to the manufacturers, organizations and bibliographic searches listed in the text.

1. STUDIES & PROCEEDINGS

The Air Force Systems Command Statement on the Defense Industrial Base, Headquarters, Air Force Systems Command, November 1980.

Analysis of Critical Parts and Materials, The Analytical Sciences Corporation, December 1980.

Appendices to the Report on the Peacetime Adequacy of the Lower Tiers of the Defense Industrial Base: Case Studies of Major Systems, R-2184/2-AF, Baumbusch, Geneese G., et. al. The Rand Corporation, November 1977.

Critical Materials Requirements in the U.S. Aerospace Industry, U.S. Department of Commerce, October 1981.

Payoff 80: Executive Report - Manufacturing Technology Investment Strategy, Headquarters, Air Force Systems Command, October 1980.

Peacetime Adequacy of the Lower Tiers of the Defense Industrial Base, R-2184/1-AF, Baumbusch, Geneese G. and Harman, Alvin Jr., The Rand Corporation, November 1977.

Proceedings of OSD Aircraft Engine Design and Life Cycle Costing Seminar, May 1978.

Proceedings: U.S. Department of Commerce Public Workshop on Critical Materials Needs in the Aerospace Industry, Wachtman, John B., U.S. Department of Commerce, National Bureau of Standards, July 1981.

Report of the Defense Science Board 1980 Summer Study Panel on Industrial Responsiveness, Office of the Under Secretary of Defense for Research and Engineering, January 1981.

2. REPORTS

Census of Manufacturers - 1977, U.S. Department of Commerce, Bureau of the Census.

Curent Industrial Reports (selected topics), U.S. Department of Commerce, Bureau of the Census.

Employment and Earnings (selected issues 1982), U.S. Department of Labor, Bureau of Labor Statistics.

Mineral Commodities Summaries - 1982, U.S. Department of the Interior, Bureau of Mines, 1982.

Minerals Yearbook - 1981, U.S. Department of the Interior, Bureau of Mines, 1982.

Minerals Yearbook - 1982, U.S. Department of the Interior, Bureau of Mines, 1983.

Survey of Current Business (selected issues 1982), U.S. Department of Commerce, Bureau of Economic Analysis.

Survey of Manufacturers - 1981, U.S. Department of Commerce, Bureau of the Census.

Producer Prices and Price Index (selected issues 1981 and 1982), U.S. Department of Labor, Bureau of Labor Statistics.

1982 U.S. Industrial Outlook for 200 Industries, with Projections for 1986, U.S. Department of Commerce, Bureau of Industrial Economics, January 1982.

1983 U.S. Industrial Outlook for 250 Industries, with Projections for 1987, U.S Department of Commerce, Bureau of Industrial Economics, January 1983.

3. PERIODICALS

Air Force Magazine - January to December 1982.

Aviation Week and Space Technology - 5 November 1979 to 28 February 1983.

Business Week - 4 January to 27 December 1982.

Forbes - 4 January 1982 to 14 February 1983.

Fortune - 4 January to 27 December 1982.

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